Kor. J. Env. Hlth., Vol. 30, No. 4, pp 347~351(2004)

Sediment Toxicity Assessment in the Intertidal Flat Zone of the Middle West Coast of Korea

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(Received Aug. 17, 2004/Accepted Oct. 16, 2004)

Abstract : A battery of sediment bioassays was performed for the sediments from the intertidal flat zone along the middle west coast of Korea to assess their potential toxicity. In the bioassays, three crustaceans, Daphnia magna, Nitocra spines, and Hyalella azteca were exposed to 16% sediments (wet weight) collected from 14 sites. Immobility(%) was checked as an endpoint after 24- and 48-h exposure of Daphnia magna and after 96-h exposure of Hyalella azteca and Nitocra spines. Among the three bioassays, the 48-h Daphnia bioassay showed the most distinct differential sensitivity in relation to sediment contamination, while the Nitocra and the Hyalella bioassays failed to show the differential sensitivity properly among the sites classified as polluted. Significantly different levels of immobility (%) were obtained between the sites classified as chemical/nutrient polluted and the sites classified as non-polluted in the Daphnia bioassays, but not in the Nitocra bioassay and the Hyalella bioassay. Some differences of toxic response to the same sediments among bioassays were observed, suggesting that there may be a chemical specificity of response sensitivity to sediment toxicity, due to differences in bioavailability of sediment toxicants among test species.

Keywords : sediment, daphnia, Nitocra, Hyalella, toxicity

Introduction

The conventional approach for the assessment of sediment quality uses the concentration of contaminants. But this is not sufficient due to several intrinsic limitations (Forbes *et al.* 1998): (1) bioavailability may vary depending on the type of sediment matrix, (2) it may not be possible to detect all contaminants, and (3) the interaction of contaminants can cause complications. Hence, the importance of using sediment bioassays has been emphasized in the ecotoxicological interpretation of sediment pollution and, recently, continuous efforts have been made to accomplish their methodological development and standardisation. In this evolutionary process, a variety of minute or micro organisms such as amphipods and bacteria have been suggested as useful test species to assess sediment toxicity (ASTM 1993; Ringwood 1997).

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The intertidal flat zone along the west coast of South Korea is one of the most famous intertidal flats in the world. The great part of its middle flats has been faced with the fate of disappearance by a wide-scaled reclamation project (Saemankeum Reclamation Project) that will be implemented by 2011. This project will produce a development area of 40,100 ha that consists of freshwater reservoir of 11,800 ha and tideland reclamation of 28,300 ha (KRDC 1996). It is not surprising that growing concern over environmental disruption has focused on this project nationally as well as internationally.

In this study, sediments from tidal flats along the middle west coast of South Korea, including Saemankeum coast, were subject to bioassays to look for the regional distribution of sediment toxicity. For the bioassays, 3 crustaceans (*Daphnia magna, Nitocra spines*, and *Hyalella azteca)* were used as test species to compare their sensitivity to sediment toxicity and evaluate their suitability as a monitoring tool for the assessment of tidal flat contamination.

Materials and Methods

Sediments were collected from tidal flats in Korea at the locations shown in Fig. 1. on October 30-31, 2000. The sampling sites were categorized into 3 groups (non-polluted, potentially polluted by nutrients, potentially polluted by chemicals and nutrients) based on the contamination sources (Table 1). Sediment samples were taken at a depth of 15-25 cm at low tide. Sampling vessels made of inert plastics were sealed with Teflon tape and carried in a cool box during transport from Korea to Sweden. Then they were stored at 4°C at the laboratory prior testing. All testing and determinations were made within 2 weeks after collection. Sediments were tested for toxicity by standardised toxicity testing procedures as described elsewhere (Dave and Nilsson, 1994; 1999). The test organisms (*Daphnia magna*, *Nitocra spines* and *Hyalella azteca*) were taken from laboratory cultures. All tests were made with 16% sediment (wet weight) at room temperature (20 ± 1°C) in duplicate. For dilution, standard reference water (ISO, 1996) was used in the tests with *Daphnia magna*, and diluted seawater (7 psu) was used in the tests with *Hyalella azteca* and *Nitocra spines*. Exposure duration was set to 24 h and 48 h for *Daphnia magna* and 96 h for *Hyalella azteca* and *Nitocra spines*. The immobility in controls (dilution water and sediment from non-polluted sites) was less than 10% in all tests, and the sensitivity to the reference chemical (potassium dichromate) of test organisms was as follows: 1.89 mg/*l* for the 24-h EC50 for *Daphnia magna*, 32.2 mg/*l* for the 96-h LC50 for *Hyalella azteca* and 15.5 mg/*l* for the 96 h LC50 for *Nitocra spines*. These values are within the accepted laboratory normal range for these tests under the specified test conditions. The difference in sensitivity to potassium dichromate is at least partly due to the difference in salinity during these tests, and it does not reflect any general difference in sensitivity for these test organisms. Comparisons of sediment toxicity between the sites classified as non-polluted and the sites

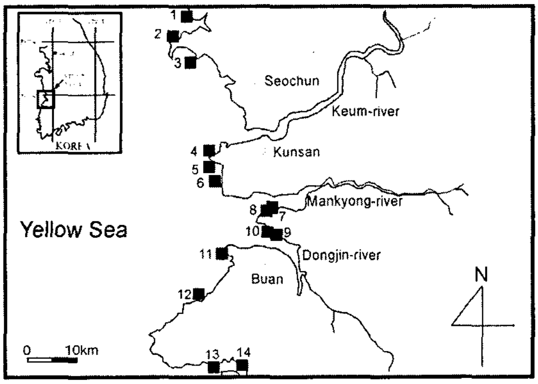
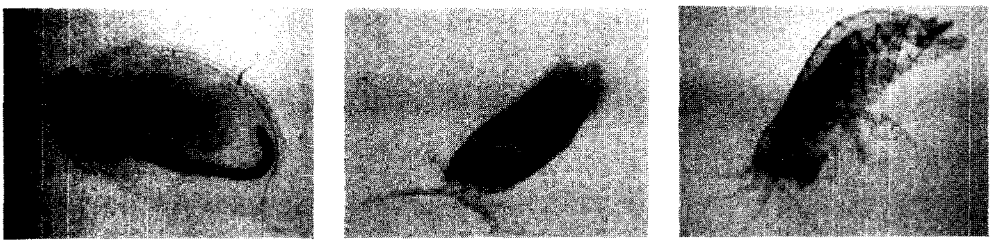


Fig. 1. Map showing sampling sites along the middle west coast of South Korea.

Table 1. Classification and brief description of sampling sites

Estimated pollution type	No. of Sampling sites (Fig. 1)	Main contamination source
Chemical/nutrient polluted	3, 4, 5, 6, 7, 8	Industrial zones, municipal sewage, livestock wastewater
Nutrient polluted	9, 10	Farming, municipal sewage
Non-polluted	1, 2, 11, 12, 13, 14	No specific source



Daphnia magna *Nitocra spines* *Hyalella azteca*

Fig. 2. Crustaceans as test species.

classified as polluted were performed by Student's t-test.

Results and Discussion

In association with methodological development and standardization of bioassays, it is essential that the sensitivity of test organisms to sediment toxicity be examined under the specified test conditions to define their advantages as suitable test species available for sediment toxicity assessment. In this study, the Daphnia bioassay showed relatively good potential to express differential response to sediment toxicity, favorably reflecting our estimation associated with contamination status around the sampling area (Fig. 3, Fig. 4). For the sediments from the sites classified as chemical/nutrient or nutrient polluted, the Daphnia bioassay showed immobility after both 24 and 48 h exposure except for the site No. 10 (nutrient polluted) and, for the sediments from the sites classified as non-polluted, it showed no immobility in all cases (Fig. 3). In the case of the sediments with actual immobility, 48 h immobility was higher than 24 h immobility except for the sediment from site No.3 in which they were the same. Marked increases of immobility between 24 h exposure and 48 h exposure were observed particularly in the sediments from the site No. 5 and No. 8. In addition, the 48 h exposure gave a wider range of immobility (6% to 25%) as compared with the 24 h exposure, implying that it may be easier to detect differences in sediment toxicity after 48 h than after 24 h. No correlation of immobility between 24 h exposure and 48 h exposure was found.

The Daphnia bioassays showed significantly different immobility levels between the sites classified as chemical/nutrient polluted and the sites classified as non-polluted while that is not the case for the Nitocra bioassay and the Hyalella bioassay (Fig. 4). It was reported that 48 h-immobility in the Daphnia bioassay offers more differential sensitivity than 96 h-LC50 in the Nitocra bioassay when they were applied to sediment toxicity assessment with the same test protocol used in the present study (Dave and Nilsson 1999). Unlike Nitocra and Hyalella, Daphnia is not benthic, but its propensity for inhabiting the sediment-water interface and feeding at the surface of sediments makes it a useful test species for the sediment bioassay (Suedel *et al.* 1993). Overall, sediment toxicity of the sampling sites in the present study was not as high as that in the Kattegat and Skagerrak, on the Swedish West coast, where 48 h immobilities for 121 sediment samples recorded in the Daphnia bioassay ranged from 0 to 95% (mean = 29%) (Dave and Nilsson 1999). It is difficult to make further comparison due to lack of data on contamination.

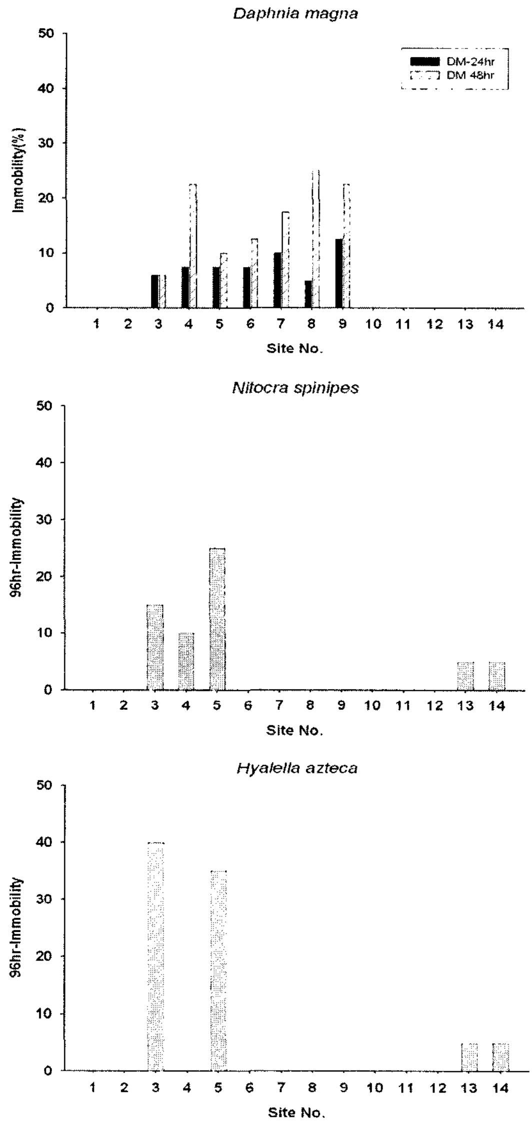


Fig. 3. Sediment toxicity to crustaceans.

In this study, the Nitocra bioassay and the Hyalella

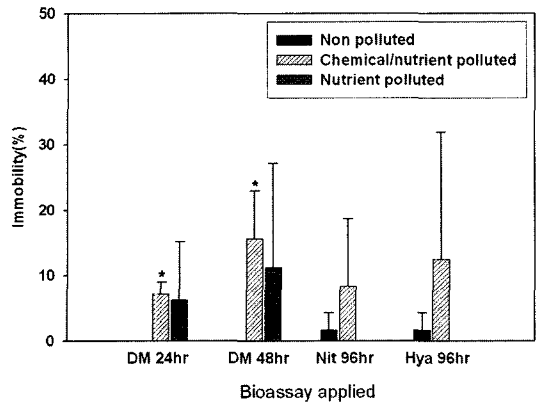


Fig. 4. Comparison of sediment toxicity according to the estimated pollution type.
*Significantly different from non polluted sites, P<0.01.

bioassay did not show the same differential sensitivity as the Daphnia bioassay, but all three bioassays identified Site 3 and Site 5 as being toxic (Fig. 3). The Nitocra ioassay showed over 10% of 96hr-immobility for the sediments from the site No.3, No.4 and No.5 and showed no or only weak (<5%) response for the rest of sediments. The Nitocra bioassay provided a slightly better differential sensitivity than the Hyalella bioassay, but its differential sensitivity was not satisfactory for the sediments from the sites classified as polluted, as compared with that provided by the Daphnia bioassay. The Hyalella bioassay has been reported to be sensitive and discriminatory to sediment toxicity (USEPA 1992; Burton *et al.* 1992). However, in the present study, the Hyalella bioassay failed to show reliable differential sensitivity among the sediments from the sites classified as polluted (No. 3~No. 10)(Fig. 3). A longer duration may be required for the Hyalella bioassay to produce better differential sensitivity. Borgmann and Munawar (1989) suggested 1 week as an appropriate assay duration of the Hyalella bioassay for the assessment of acute sediment toxicity.

Relatively high responses for the sediments from the site No. 3 and No. 4 were observed in the Nitocra bioassay and the Hyalella bioassay. Considering that the high response for those 2 sediments was not observed in the Daphnia bioassay, it can be assumed that there may be a chemical specificity of response sensitivity to sediment toxicity, due to the different bioavailability of sediment toxicants among test species. For the sediments from the sampling sites classified as non-polluted, all bioassays showed very week sediment toxicity below 5% of immobility, demonstrating that the stable response baseline could be readily provided for sediment toxicity assessment. It was somewhat strange that the Daphnia assay showed different responses to the 2 neighboring sites classified as nutrient polluted. A relatively high immobility for the site No. 9 and no immobility for the site No. 10 were found. In the Nitocra bioassay and the Hyalella bioassay, no immobility was recorded for the sediments from those 2 sites. Further investigation including the determination of sediment contaminants is required to examine what caused strong sediment toxicity to Daphnia in the site No. 9.

This study has shown that sediment bioassays can be used to separate polluted from non-polluted sediments, but also that a battery of tests should be used. In this study, the Daphnia bioassay was best correlated with the expected degree of contamination, but it may also be that the other bioassays are better related to the effects of pollution on the benthic infauna. The latter was not assessed in the present study. A commonly used approach in sediment quality assessments is the sediment quality triad, which uses data from both chemical analyses, bioassays and infaunal composition(Chapman 1989; Carr *et al.* 1996).

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